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SYNOPSIS

ON

Study of Creeping Waves and Surface Diffraction in Dielectric–Coated Conductors

BY

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For

PhD Degree in Physics (Faculty of Science)

Under the Supervision

of

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B. N. MANDAL UNIVERSITY MADHEPURA

SYNOPSIS FOR PhD DEGREE IN PHYSICS

FACULTY OF SCIENCE

1. TITLE OF THE RESEARCH

Study of Creeping Waves and Surface Diffraction in Dielectric–Coated Conductors

2. WORK PLAN

(a) Purpose and Need of the Study

Electromagnetic wave interaction with curved conducting bodies and with conductors covered by dielectric layers produces a class of surface-guided, slowly attenuating fields commonly called creeping waves. Creeping waves propagate along convex surfaces, and — after curving around the object — re-radiate into the far field producing characteristic scattering features such as shadow-region fields, and resonance-like peaks in radar cross section. When a dielectric coating is present on a conductor, the surface-guided modes and their attenuation, phase velocity, and coupling to space waves are significantly modified. The dielectric coatings can enhance, suppress or convert creeping-wave contributions. It can also introduce leaky surface modes whose dispersion depends on coating permittivity, thickness and loss. Understanding these phenomena is essential for accurate prediction and control of scattering, antenna performance, radar cross-section engineering, and electromagnetic compatibility in coated structures used across microwave, millimeter-wave and terahertz systems.

As frequencies move into millimeter-wave and sub-mm regimessuch as 5G/6G, automotive radar, remote sensing and THz imaging the coating thicknesses

approach a meaningful fraction of wavelength, so small changes in coating properties strongly affect creeping-wave behavior. Accurate models are required for RCS prediction, stealth design, wave guiding on curved surfaces and antenna radome design. Engineers exploit or suppress creeping waves in applications ranging from stealth to sensor design. Dielectric coatings are an accessible design parameter; systematic study can provide design rules. Recent studies demonstrate both suppression and engineered enhancement of creeping-wave contributions via material and structural design. Classical asymptotic theories (Fock's approach, the Geometrical Theory of Diffraction & its uniform formulations) give deep insight but have limitations for multi-layered, lossy and anisotropic coatings and for moderate size parameters. Numerical tools (FEM, MoM, FDTD, UTD-based codes) can handle specifics but are computationally expensive and sometimes lack clear physical interpretation. There is a need to combine asymptotic analysis, eigenmode dispersion analysis for coated surfaces, and high-fidelity numerics together with experimental verification. Novel dielectrics (lossy, dispersive, anisotropic, metamaterial or gradient-index coatings) open possibilities to tailor creeping-wave dispersion — but their effects are not comprehensively characterized, particularly on curved conductors. This motivates a systematic theoretical, numerical and experimental study.

In this project we will analyze the dispersion relations of surface-guided (creeping and leaky) modes supported by dielectric-coated conductors.

Efforts will be made to improve asymptotic expressions for creeping-wave diffraction from coated convex bodies. We will also try to produce design guidelines for applications in RCS control and radome/antenna engineering.

(b) <u>Details of the Project with Chapterization</u>

Proposed thesis structure will contain the following chapters:

Chapter 1. This part will contain the Introduction (literature overview, problem statement) Motivation, objectives, scope and significance of the research project.

Brief history of Sommerfeld, Fock, Keller, Malyshev/others on creeping waves along with more recent studies on dielectric coated cylinders/spheres and applications will be presented here.

The creeping waves, surface diffusion/diffraction, leaky waves, attenuation, complex wave number and size parameter would also be explained.

Chapter 2. In this part the theoretical foundations and classical models will be presented. The Maxwell's equations in layered media, the boundary conditions for conductor–dielectric interfaces will also be described. The geometrical Theory of Diffraction (GTD), Uniform Theory of Diffraction (UTD), Fock's theory of diffraction around convex bodies will also be explained.

Chapter 3. In this part of thesis the dispersion analysis of surface-guided modes on dielectric-coated conductors, the formulation of eigenvalue problems for cylindrical and spherical geometries use separation of variables and boundary matching will be studied.

Chapter 4. In this part of thesis asymptotic evaluation of creeping-wave diffraction for coated bodies will be studied. Contour integral representations of scattering fields (from eigenfunction expansions). Development of uniform asymptotic formulas valid near shadow boundaries and for finite observation angles; inclusion of coating-modified phase and attenuation factors will also be studied.

Chapter 5. In this part of the thesis Numerical methods and full-wave simulations would be presented. Description and setup of numerical solvers such as Method of Moments (MoM) with layered Green's functions, Finite Element Method (FEM), Finite-Difference Time-Domain (FDTD), and high-frequency UTD implementations would be done.

Large parametric sweeps: RCS vs aspect angle, coating thickness, frequency for cylindrical & spherical prototypes.

Chapter 6. In this part of the thesis experimental design and measurement would be presented. The monostatic/bistatic RCS, near-field scans to capture surface-guided energy, time-gating to separate creeping contributions would also be described.

Chapter 7. In this part of study we will present Results, discussion, and application scenarios

Chapter 8. In the last chapter the Conclusions and future workrelated to our study will be given.

(c) Methodology

This study follows an integrated theoretical–numerical–experimental methodology that ensures physical insight, computational accuracy and empirical validation.

In the first step the mathematical modeling & analytical methods will be studied

The governing equations and boundary conditions to solve the time-harmonic Maxwell's equations (e^{-iωt}) in cylindrical/spherical coordinates for a three-region structure: region I (conductor core, treated as PEC or finite-conductivity metal), region II (dielectric coating with complex permittivity $\varepsilon(\omega) = \varepsilon' - j\varepsilon''$), and region III (exterior free space).

We may apply boundary conditions to derive characteristic equations for modal coefficients. We may express scattered field as contour integral by converting eigenfunction series to an integral (Watson transformation). Identify contributions from branch points, saddle points and poles. We will evaluate pole residues associated with surface guided modes — these describe creeping-wave contributions. Use steepest descent to evaluate radiative remainder.

Method of Moments (MoM) with layered-medium Green's functions for axisymmetric bodies — effective for frequency-domain RCS and scattering problems would also be studied here. We may compute near-surface field amplitude and phase to identify creeping-wave energy propagation distance and conversion to radiated waves.

We will also study the Near-field scanning capability (probe scanner) to measure surface fields if available; near-to-far-field transformation to relate near-field creeping energy to far-field scattering.

We will also present the difficulty measuring weak creeping contributions due to dynamic range limits. Mitigation: Use time-gating, increase object size (scale-model techniques), and high-sensitivity receivers.

(d) References

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I testify that I am in a position to devote time for this research work and undertake to complete this research work within specified maximum time limit.

Full signature of the research scholar

With date.

The candidate has undertaken to complete the research work under my supervision and guidance under the time limit.

Full signature of the supervisor

with date designation and address.